

Partial Flexor Tendon Laceration Assessment: Interobserver and Intraobserver Reliability

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Abstract

Accurate assessment of partial-thickness flexor tendon lacerations in the hand is difficult owing to the subjectivity of evaluation.

In this study, we created 12 partial-thickness flexor tendon lacerations in a cadaveric hand, evaluated the accuracy of 6 orthopedic residents and 4 fellowship-trained hand surgeons in estimating the percentage thickness of each laceration, and assessed the groups' interobserver and intraobserver agreement. The 10 participants estimated each laceration independently and on 2 separate occasions and indicated whether they would repair it. The actual thickness of each laceration was calculated from measurements made with a pair of digital microcalipers.

Overall estimates differed significantly from calibrated measurements. Estimates grouped by residents and fellowship-trained hand surgeons also differed significantly. Third-year residents were the most accurate residents, and fellowship-trained hand surgeons were more accurate than residents. Overall interobserver agreement was poor for both readings. There was moderate overall intraobserver agreement. Fellowship-trained hand surgeons and first-year residents had the highest intraobserver agreement.

These results highlight the difficulty in accurately assessing flexor tendon lacerations. Accuracy appears not to improve with surgeon experience.

How to manage complete flexor tendon lacerations in the hand is well documented and a subject of relative agreement among authors. However, treatment of partial flexor tendon lacerations is controversial and lacking clear consensus in the literature. Managing these injuries can be challenging, as clinicians must weigh the diminished tensile strength in the injured tendon and the potential for later complications (eg, entrapment, triggering, rupture) against the negative effects of tenorrhaphy.¹ Several studies have found impaired tendon gliding on the basis of bulk and inflammatory reaction secondary to suture material within the flexor sheath as well as decreased tendon strength after tenorrhaphy.²⁻⁶ This finding led the investigators to recommend nonsurgical management for partial lacerations up to as much as 95% of the cross-sectional area (CSA) of the tendon. According to a survey by McCarthy and colleagues,⁷ 45% of 591 members

of the American Society for Surgery of the Hand (ASSH) indicated they would perform tenorrhaphy for a laceration that involved more than 50% of the tendon.

However, accurate assessment of partial-thickness flexor tendon lacerations is difficult owing to the subjectivity of evaluation. In the survey just mentioned,⁷ the majority of surgeons used the naked eye to make assessments, and only 14% used other means, such as a ruler, a pair of calipers, or loupe magnification. In addition, flexor tendon injuries are often evaluated under less than ideal circumstances—a dirty or bloody field, poor lighting, an uncomfortable patient.

We conducted a study to determine the interobserver and intraobserver reliability of surgeons assessing the percentage of CSA injured in partially lacerated digital flexor tendons. We hypothesized that participants' accuracy and agreement would be poor.

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Materials and Methods

Eight 1-cm transverse, volar skin incisions were made over the midportions of the middle and proximal phalanges of the index, middle, ring, and small fingers of a fresh-frozen human cadaver hand (**Figure 1**). The tendon sheaths were incised, and the flexor digitorum profundus tendons to each digit were delivered through the wound. With use of a method described previously by Manning and colleagues,⁸ the tendon was then placed over a flat metal post to be used as a cutting board, and

the proposed laceration site was marked with ink. Under loupe magnification, a No. 15 blade was used to create a partial transverse, volar-to-dorsal laceration in each tendon.⁸ The goal was to create lacerations of about 30%, 50%, and 70% of the total CSA of the tendon. The tendons were then returned to the wound, and visibility of the marked laceration within the wound was ensured. A similar exercise was performed at the level of the proximal palmar crease. Four flexor digitorum superficialis tendons were exposed through 1-cm transverse incisions, and partial lacerations were made in the volar substance of the tendons. The tendons were then returned to the wound, resulting in 12 partially lacerated tendons (8 flexor digitorum profundus, 4 flexor digitorum superficialis).

Six orthopedic surgery residents (2 postgraduate year 1 [PGY-1], 2 PGY-3, 2 PGY-5) and 4 fellowship-trained hand surgeons participated in our study. Each was asked to evaluate the tendons and determine the percentage of total CSA lacerated. Loupe magnification and measuring tools were not permitted, but participants were allowed to handle the tendons. In addition, they were asked if they would perform tenorrhaphy on the injured tendons, given only the amount of injury. The participants repeated this exercise 4 weeks later.

After all measurements were made, a longitudinal incision was made down each of the digits, and the flexor tendons were exposed within the flexor sheath. The transverse incisions in the palm were connected to expose the flexor digitorum superficialis tendons. Under an operating microscope, a pair of digital microcalipers (Kobalt 0.5-ft Metric and SAE Caliper; **Figure 2**) accurate to 0.01 mm was used to measure the external width (a) and height ($b + b'$) of the tendons just proximal to the lacerations. Measurements were made with the caliper blades just touching the edges of the lacerated tendon, thus minimizing deformation of the tendon. Other measurements made at the laceration site were width of the remaining tendon (c) and height of the remaining tendon (b'). CSA of the tendon was calculated assuming a regular ellipsoid shape and using the equation:

$$Area = \frac{1}{2}\pi a(b+b')$$

The area of the tendon injured was determined by calculating the area under a parabola and using the equation:

$$Area = \frac{2}{3}c[(b+b')-b']$$



Figure 1. Eight 1-cm transverse, volar skin incisions were made over midportions of middle and proximal phalanges of index, middle, ring, and small fingers of a cadaveric hand.



Figure 2. Under operating microscope, a pair of digital microcalipers was used to measure external width and height of tendons just proximal to lacerations. Measurements were made with caliper blades just touching edges of the lacerated tendon, thus minimizing deformation of tendon.

Last, the percentage of total CSA lacerated was calculated using the equation:

$$\frac{\text{Area' (area of injured tendon)}}{\text{Area (total area)}} \times 100\%$$

Statistical analysis was performed to determine accuracy and interobserver and intraobserver reliability. Paired *t* tests were used in the assessment of accuracy to determine if there were differences between estimated and calibrated measurements.

Results

The 10 participants' estimates differed significantly ($P < .0006$) from the calibrated measurements, as did residents' estimates ($P < .0025$) and fellowship-trained hand surgeons' estimates ($P < .0002$). Estimates were scored 1 to 5 on the basis of proximity to calibrated measurements (Table 1). Thus, more accurate estimates received lower scores. Individual estimates were then scored and stratified into groups for comparison. Third-year residents were the most accurate residents, and there was no difference in accuracy between residents and fellowship-trained hand surgeons. These results are listed in Table 2. Once overall and grouped accuracy was analyzed, κ statistics were calculated to compare interobserver and intraobserver reliability. Overall interobserver agreement was poor for both initial readings ($\kappa = 0.16$) and secondary readings ($\kappa = 0.16$), indicating poor strength of agreement between individuals both initially and secondarily. Table 3 presents the κ interpretations. There was moderate overall intraobserver agreement (45.83%), indicating participants' secondary estimates agreed with their primary estimates 46% of the time. Fellowship-trained hand surgeons and first-year residents had the highest intraobserver agreement (50.0%). These results are listed in Table 4.

Discussion

Accurate assessment of partial flexor tendon lacerations is difficult and subjective. There is no standardized method for determining the extent of injury, regardless of whether the evaluation is performed in an emergency department or in the operating room. As McCarthy and colleagues⁷ noted in their survey of ASSH members, naked eye assessment was by far the most popular means of estimating percentage injured in partial lacerations, and only 10% of the survey respondents used intraoperative measuring devices. Our study showed that partic-

ipants agreed with one another less than 50% of the time when evaluating injuries without the aid of measuring devices. In addition, interobserver agreement in this study was about 50%, highlighting

Table 1. Grading Scale for Individual Estimates

% Within Actual Measurement	Grade
0-10	1
11-20	2
21-30	3
31-40	4
>40	5

Table 2. Accuracy Comparison by Group

Group	Mean Accuracy
Residents	
PGY-1	3
PGY-3	2.625
PGY-5	3.041667
All	2.8888
Attendings	2.864583

Abbreviation: PGY, postgraduate year.

Table 3. κ Statistic Interpretation

κ	Strength of Agreement
0-0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Good
0.81-1.00	Very good

Table 4. Intraobserver Agreement by Group

Group	Mean Intraobserver Agreement
All 10 participants	45.834
Residents	
PGY-1	50
PGY-3	41.665
PGY-5	37.5
All	43.055
Attendings	50.0025

Abbreviation: PGY, postgraduate year.

the difficulty in making an accurate and reproducible assessment.

In a study of canine flexor tendons, McCarthy and colleagues⁹ found calipers are inaccurate as well and do not provide a reliable means of assessing partial flexor tendon lacerations. They compared caliper measurements with laser micrometer measurements, and the differences averaged 29.3%. They suggested that methods for calculating loss of CSA and for creating precise lacerations must be developed in order to evaluate treatments. One such method is the "tenotome," devised by Hitchcock and colleagues¹⁰: A device with standard scalpel blades is used to make uniform lacerations in tendons by leaving a constant area of the tendon intact, regardless of the size or shape of the original tendon. Measurements made with calipers or rulers assume the tendon has a regular ellipsoid shape, but in reality the shape is a double-ellipse, particularly within the flexor sheath.

Dobyns and colleagues¹¹ observed that changes in CSA size can be related to changes in the size of the bundle pattern of the tendon. They found that, on average, the radial bundle comprised about 60% of the total CSA of the tendon. This finding was clarified by Grewal and colleagues.¹² Using histologic sections of tendons plus photomicrographs, they determined that, in zone II of the index and small fingers, the ulnar bundle had an area consistently larger than 50% and the radial bundle less than 50% of the total tendon area. In the ring and middle fingers, the areas of both bundles were almost 50% of the total tendon area. The authors suggested that, using this bundle pattern theory of injury, surgeons could more accurately evaluate the extent of injury with the naked eye.

One of the questions that prompted our study is how reliable is the information a surgeon receives regarding a partial flexor tendon injury evaluated by someone else in another setting. What is done with this information is another question. The scenario can be considered in 2 settings: emergency department and operating room.

Given the poor accuracy and interobserver agreement found in our study, along with the inaccuracy of caliper and ruler measurements, it seems decisions to perform tenorrhaphy based on reported percentages lacerated are unreliable. Our results showed that the ability to accurately assess partial tendon injuries does not improve with surgeon experience, as fellowship-trained hand surgeons were not statistically more accurate or consistent than residents. To this effect,

one institution treats all its partial flexor tendon lacerations with wound inspection and irrigation in the emergency department, under digital block and after neurovascular injury has been excluded.⁸ If the patient is able to actively flex and extend the digit without triggering, then the wound is closed without closing the tendon sheath, a dorsal blocking splint is applied, and motion is begun early, 48 hours later, regardless of laceration severity.

Once the decision has been made to go to the operating room and the injury is being evaluated, what should be done with the information from the measurement, whether made with loupe magnification, calipers, rulers, or the naked eye? Surgeons must weigh the risks for triggering, entrapment, and rupture of untreated partial tendon lacerations¹ with the added bulk and potential for adhesions, along with the tensile strength reduction that accompanies tendon repair. Both Reynolds and colleagues¹³ and Ollinger and colleagues¹⁴ found tensile strength significantly diminished in sutured tendons. Ollinger and colleagues¹⁴ showed a decrease in tendon gliding after surgical exposure and tenorrhaphy for partial tendon lacerations. Reynolds and colleagues¹³ concluded that surgical repair leads to poorer results than nonsurgical treatment.

Clinical studies have demonstrated excellent results with nonintervention, and in vivo and in vitro studies have indicated that early motion can be initiated in partial lacerations of up to 95% of total CSA. Wray and Weeks⁶ treated 26 patients with partial lacerations varying from 25% to 95% of total CSA and noted 1 incidence of trigger finger (which resolved) and no late ruptures. They advocated treatment with early motion and excision or repair of beveled partial lacerations with simple sutures. Stahl and colleagues² reported comparable outcomes in children with partial lacerations up to 75% of total CSA treated with and without surgery and noted no complications in either group. In a biomechanical study, Hariharan and colleagues⁴ found lacerations up to 75% can withstand forces associated with active unresisted mobilization.

Conversely, how many patients or surgeons want to return to the operating room to fix a late rupture when it could have been repaired in the primary setting? Schlenker and colleagues,¹ reporting on a late flexor pollicis tendon rupture that required tendon grafting, recommended exploration and primary repair of all partial flexor tendon lacerations. Often, it is difficult to determine whether surgical repair is necessary to ensure the best outcome for the patient.

Our study results showed that, in the evaluation of flexor tendon lacerations, both accuracy and interobserver agreement were poor among residents and fellowship-trained hand surgeons, and intraobserver agreement was moderate. Third-year residents were the most accurate residents, and there was no difference in accuracy between residents and fellowship-trained hand surgeons. Our results highlight the difficulty in making accurate assessments of flexor tendon lacerations owing to the subjectivity of evaluation, which appear not to improve with surgeon experience.

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